Physical and Mechanical Properties of Oil Palm Fibres and Polyethylene Hybrid Composite

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ABSTRACT

Hybrid composite boards were manufactured from oil palm trunk (OPT), frond (OPF), empty fruit bunch (EFB) and polyethylene. Four different plastics content of 0%, 5%, 12% and 20% were used in this study. The boards were manufactured to target density of 850 kg m$^{-3}$. Urea formaldehyde (UF) adhesive was used as a binder at resin level of 10%. The properties of the resultant boards were determined according to the Japanese Industrial Standard (JIS-A-5906, 1983). All the OPF boards and all the other boards with 5% and 12% plastic content irrespective of the fibre types satisfied the 200-type board for modulus of rupture as stated in the JIS-A-5906. The OPT boards and all other boards with 0% and 20% plastic content passed the JIS-A-5906 150-type board while the EFB boards only passed the JIS-A-5906 50-type board. For internal bonding (IB), all the boards were able to meet the requirement of JIS-A-5906 300-type board. In the case of thickness swelling (TS), all the boards failed to meet the requirement as specified in the JIS-A-5906 standard. However, the dimensional stability of the boards increased with increased quantity of plastic used.

INTRODUCTION

Oil palm fibres have big potential to be a substitute for or a supplement to wood. The development of wood composites has been largely based on the use of softwood and hardwood timbers. However, the advances in technology have enabled agricultural wastes and other industrial by-products to be utilized as well. Research on combining lignocellulosics, including oil palm biomass, with other materials, such as glass, metal, inorganic, plastic and synthetic fibres, in producing new materials are being carried out (Youngquist and Rowell, 1989). One of the disadvantages of wood composites is its high affinity for moisture that can have adverse effects on its characteristics and properties (Youngquist and Rowell, 1989; Suchland and Woodson, 1991). Therefore, the development of wood composites with greater dimensional stability and improved physical and mechanical properties is necessary. Improvement of these properties can be achieved by combination with plastic polymers. Lignocellulosics fibres blended with polyolefin plastics can be used to produce an array of high performance reinforced composite products. These composites have been reported to have better properties, such as lightweight, improved acoustical impact.
and heat reformability properties (Maloney, 1977).

In this study, a hybrid composite board was made from oil palm fibres and polyethylene. The board was tested in accordance with the JIS-A-5906 Standard (Anon., 1983) to determine its physical and mechanical properties.

**OBJECTIVE**

The primary objective of this study was to investigate the mechanical properties of hybrid composite boards from oil palm biomass and polyethylene.

**MATERIALS AND METHODS**

A laboratory experiment was conducted to investigate the physical and mechanical properties of hybrid composite boards 3 mm thick. Twenty-four (32 cm x 32 cm) samples of the boards were prepared for the testing. The oil palm fibres used for the sample preparation were obtained from the Malaysian Palm Oil Board (MPOB) while the boards were made at the Forest Research Institute of Malaysia (FRIM). The samples were cut to their dimensions in accordance with the Japanese Industrial Standard (JIS) before the testing.

The raw materials used in this study were:

- a) OPF fibre with parenchyma;
- b) OPT fibre with parenchyma;
- c) EFB fibre with parenchyma;
- d) plastic (polyethylene) (at 0%, 5%, 12% and 20% content);
- e) glue (urea formaldehyde) (to 10% resin content); and
- f) wax (1%).

OPT, OPF and EFB chips were cold refined. The fibres obtained were dried in an electric oven to 8% to 12% moisture. Later the fibres were fluffed to tease them out before further drying to 5% to 7% moisture. The fibres were then used to prepare the boards. The oil palm fibre and polymer moisture contents were first determined by a moisture meter. All the materials used in the board preparation were then weighed to predetermined weights. The fabrication of the boards was done using a non-woven process. The boards were then conditioned at room temperature for 24 hr.

**Testing Procedure**

The testing procedure followed the Japanese Industrial Standard (JIS-A-5906, 1983) for medium density fibreboard (MDF). The tests conducted were for bending strength, IB, TS, water absorption, density and moisture content.

**RESULTS AND DISCUSSION**

**Physical Properties of the Boards**

All the boards manufactured in this study were brownish in colour since the natural colour of the fibres used was also brownish. However, the EFB board was darker than both the OPF and OPT boards with the OPF board being the lightest.

*Table 1* indicates that the addition of plastic improved significantly the stability of the boards. All the boards with plastic had lower TS. The TS of the boards decreased with increased plastic content. Among the boards without polyethylene, the OPT board had the highest TS while the EFB board had the lowest. This may be due to the presence of oil in the EFB fibre. Among the boards without plastic, the OPF board had the highest water absorption (WA). For the boards with plastic, WA showed a similar trend to TS with decreasing WA with increased plastic content.

**Mechanical Properties of the Boards**

*Table 1* shows that the OPF board had the highest density followed by the OPT and EFB boards. It also shows that the boards with 12% plastic had the highest densities whereas the boards with 0% plastic content had the lowest densities. Statistically, they were not significantly different (*Table 1*). The interaction between fibre and plastic was not significant for density. The different fibres did not significantly affect the density. It is possible that the polyethylene had filled up the spaces in the fibre matrix, consequently, increasing the densities of the boards to similar levels.

*Table 1* also indicates that the OPT board had the highest Modulus of Elasticity (MOE) followed by the OPF and EFB boards. It also shows that the board with 12% plastic had the highest densities whereas the board with 0% plastic content had the lowest densities. The interaction between fibre and plastic was not significant for density. The different fibres did not significantly affect the density. It is possible that the polyethylene had filled up the spaces in the fibre matrix, consequently, increasing the densities of the boards to similar levels.

*Table 1* also indicates that the OPT board had the highest Modulus of Elasticity (MOE) followed by the OPF and EFB boards, respectively. The residual parenchyma in the fibre might have resulted in the higher MOE in the OPT board compared to the OPF and EFB boards. *Table 1* reveals that the boards with 5% plastic had the highest MOE among the hybrid...
TABLE 1. BOARD PROPERTIES

<table>
<thead>
<tr>
<th></th>
<th>EFB (a)</th>
<th>OPF (b)</th>
<th>OPT (c)</th>
<th>Average (a)</th>
<th>5% (a)</th>
<th>10% (b)</th>
<th>20% (c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOE (MPa)</td>
<td>929.0</td>
<td>1 668.0</td>
<td>1 996.0</td>
<td>1 531.06</td>
<td>1 902.76</td>
<td>1 788.22</td>
<td>1 490.28</td>
</tr>
<tr>
<td>MOR (MPa)</td>
<td>10.21</td>
<td>28.27</td>
<td>15.19</td>
<td>17.89</td>
<td>21.17</td>
<td>20.34</td>
<td>18.94</td>
</tr>
<tr>
<td>IB (MPa)</td>
<td>0.66</td>
<td>1.05</td>
<td>0.80</td>
<td>0.64</td>
<td>0.95</td>
<td>0.98</td>
<td>0.78</td>
</tr>
<tr>
<td>Density (kg m(^{-3}))</td>
<td>779.3</td>
<td>807.77</td>
<td>789.56</td>
<td>792.22</td>
<td>846.77</td>
<td>890.14</td>
<td>814.40</td>
</tr>
<tr>
<td>MC (%)</td>
<td>5.52</td>
<td>6.55</td>
<td>5.6</td>
<td>6.22</td>
<td>5.35</td>
<td>5.05</td>
<td>4.81</td>
</tr>
<tr>
<td>TS (%)</td>
<td>21.61</td>
<td>37.12</td>
<td>37.74</td>
<td>32.15</td>
<td>27.11</td>
<td>22.98</td>
<td>17.72</td>
</tr>
<tr>
<td>WA (%)</td>
<td>84.43</td>
<td>95.98</td>
<td>85.72</td>
<td>88.71</td>
<td>73.49</td>
<td>64.81</td>
<td>61.05</td>
</tr>
</tbody>
</table>

Note: groups followed by a common letter in brackets are not significantly different from one another at the 95% significant level.

boards. The value decreased with increasing plastic content. This could be due to the fact that as the plastic content increased, the boards acquired increased plasticity, thereby reducing the MOE. The table also shows that for the boards without polyethylene, the board from OPF had the highest Modulus of Rupture (MOR) followed by the OPT and EFB boards. The board from EFB had the lowest MOR. Among the hybrid boards, the board with 5% plastic had the highest MOR. The boards without plastic had the lowest MOR. As indicated in Table 1, the polyethylene improved the IB. Without polyethylene, the board strength was lower. However, 5% plastic was the critical value as beyond this, the boards became more plastic, accompanied by lower strength. The lower strength might not be due to the polyethylene but weaker bonding. The bonding of polyethylene with UF should be studied at the macroscopic level to understand the mechanism in more detail. Table 1 shows that the OPF board had the highest IB followed by the OPT and EFB boards, respectively. Among the hybrid boards, those with 12% polyethylene had the highest IB while those with 0% plastic had the lowest IB. Density was not significantly different at the 5% level. Furthermore, the interaction between the fibres and plastic showed no significant difference in density. Addition of more fibre also did not significantly affect the density. All types of boards had significantly different MOE, MOR and IB as shown in Table 1.

CONCLUSION

In this study, it can be concluded that the dimensional stability of the hybrid boards increased with the plastic content. In the MOR test, all the OPF boards and all the hybrid boards with 5% and 12% plastic, irrespective of the fibre type, passed the JIS-A-5906 200-type board test. The OPT board and the hybrid boards with 20% plastic passed the JIS-A-5906 150-type board test. The EFB board only passed the JIS-A-5906 50-type board test. In the IB test, all the boards were able to meet the requirements for 300-type board in JIS-A-5906. The TS test indicated that all the boards failed to meet the requirements specified in JIS-A5906. However, the margin of failure decreased with increased plastic content.

For better physical and dimensional stability, the oil palm fibres should be used without parenchyma since parenchyma tends to absorb moisture and this will affect the dimensional stability of the manufactured boards. In manu-
facturing thin MDF (3 mm) using UF resin, several factors should be considered such as the pressure and pressing time. This improves the mechanical properties of the hybrid composite because adequate pressure and pressing time will result in good compaction of the fibre and also allow the resin to completely cure and increase the inter-bonding of the fibres. The bonding characteristics and properties of the polyethylene should be further studied at the macro-level to understand its overall contribution to strength in the hybrid board. Further studies should also be carried out on the cushioning effect of parenchyma on the bending properties of the composites, as this study has indicated that trunk fibre (the most parenchymatous tissue) gave the highest MOE.

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REFERENCES


